G+ Safe by design

Workshop report: WTG access and egress

G+ Global Offshore Wind
Health & Safety
Organisation

In partnership with

energy institute

G+ SAFE BY DESIGN WORKSHOP REPORT:
WTG ACCESS AND EGRESS

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1 EXECUTIVE SUMMARY

The latest G+ Global Offshore Wind Health and Safety Organisation (G+) Safe by Design workshop focused on the issues associated with access and egress throughout a WTG and substructure (transfer from vessel/helicopter was not in scope). This included the design/infrastructure of the WTG and human factors considerations. The workshop, comprising several data gathering and data analysis activities, was held in Amsterdam on 30 November 2017. The workshop format was developed to explore access/egress issues with a focus on Safe by Design principles.

Across the workshop, many common and inter-related issues and associated recommendations were identified.

1.1 RECOMMENDATIONS

- There can be significant variance in the toolbox talk/pre-sail brief delivered or received by offshore technicians. It is recommended that G+ investigates the feasibility of producing good practice guidance on how to prepare and deliver an effective toolbox talk/pre-sail brief.
- Many of the causes of slips, trips and falls are mitigated by relatively simple good housekeeping and workplace organisation practices. Therefore, the G+ should explore the feasibility of producing good practice guidance on implementing the 5S methodology within the WTG working environment.
- Supervisory leadership in safety culture and behaviours is perceived to be varied and those being promoted into supervisory roles could be supported better to aid the transition. A review across G+ member organisations is recommended to establish whether any programmes currently exist within individual organisations which assist good technical staff to make the transition to supervisory positions. If good practice is available it should be shared, and if not then the feasibility of enabling this should be considered.
- The G+ should create an information sharing mechanism to facilitate the distribution of existing HAZID/HAZOP outputs. It is also recommended that good practice for undertaking these activities is identified and a common set of templates and guidance is created.
- The perception of the groups was that there was a lack of adequate and suitable anchor points across the WTG fleet. It is recommended that work is undertaken to determine if this issue exists and if so, identify realistic improvement opportunities. This should be in the form of a recommendation report.
- Hatches across the WTG fleet were identified as a significant hazard and frustration for technicians due to many issues, including but not limited to: pinch points; poor quality or no dampeners; poor mounting points and latches; self-closing onto personnel; risk of being left open and a resultant fall from height etc. It is recommended that work is undertaken to identify realistic improvement opportunities. This should be in the form of a recommendation report.
- Many unsafe acts could be attributed to technicians having to adapt how they perform activities due to the design of the WTG and/or associated components and equipment. There is also a perception that the users are not being adequately considered during the design stage. It is recommended that as an industry, a formal, robust and consistent feedback loop is implemented between users (technicians) and designers.
- The G+ should consider a benchmarking study to identify good practice of tools/equipment inventory and tracking systems used across member organisations, and any near future innovations being considered. The study could also highlight the benefits of how new technology helps organisations track their equipment to ensure that the right tool is available for each job without teams having to carry several duplicates.

2 BACKGROUND AND INTRODUCTION

2.1 BACKGROUND

The G+ comprises the world's largest offshore wind developers who have come together to form a group that places health and safety at the forefront of all offshore wind activity and development. The primary aim of the G+ is to create and deliver world class health and safety performance across all of its activities in the offshore wind industry. The G+ has partnered with the Energy Institute (EI) to develop materials, including good practice guidelines, to improve health and safety performance. Through sharing and analysis of incident data provided by G+ member companies, an evidence-based understanding of the risks encountered during the development, construction and operational phases of a wind farm project has been developed. This information has been used to identify the health and safety risk profile for the offshore wind industry.

In 2014, the Crown Estate asked the G+ to take over the running and delivery of their Safe by Design workshops. The Crown Estate had run a number of these previously, covering topics such as diving operations, lifting operations, wind turbine design and installation and the safe optimisation of marine operations.

By bringing the Safe by Design workshops into the G+ work programme, the G+ aims to explore industry operations and technologies with a focus on Safe by Design principles. The G+ workshops examine the current design controls relating to a topic, discuss where current design has potentially failed, identify opportunities for improvement and then seek to demonstrate the potential risk reduction to be gained from these new ways of thinking and operating.

To date five workshops have been held under the auspices of the G+ covering: marine transfer/access systems; escape from a nacelle in the event of a fire; lifting operations; WTG service lifts, and davit cranes. The outputs from four of these workshops have been made available in reports which can be downloaded from the G+ website to be used as a reference by the industry.

2.2 INTRODUCTION

From data analysis and feedback received by the G+, general access and egress within a WTG was identified as an area that should receive additional focus. Therefore, under the direction of the G+ Focal Group, a Safe by Design workshop on access/egress with WTG was held on 30 November 2017 in Amsterdam, Netherlands.

The outputs from this workshop are documented in this report.

3 METHOD/AGENDA/ATTENDANCE

3.1 METHOD

A one-day workshop was held on 30 November 2017 in Amsterdam, bringing together stakeholders and specialists from across the industry to consider the issues associated with access/egress in a WTG and substructure (transfer from vessel/helicopter not in scope) in the offshore environment. After opening remarks from Frank Monaghan, Health and Safety Director, ScottishPower Renewables, the workshop commenced with a short presentation providing guidance on the workshop exercises to follow.

Stage 1 Exercises

- Hazard identification
  - Brainstorming techniques were used to identify hazards associated with access/egress in a WTG and substructure.
  - Large WTG diagrams were used to capture the location of hazards and these hazards were rated in terms of their relative significance.
- Design issues identification
  - The most significant hazards were interrogated to identify the design issue(s) causing these hazards and the current controls/mitigations.
  - Potential solutions / improvement ideas around the design issues and associated hazards were also identified.
- Potential unsafe acts identification
  - 'Potential/theoretical' unsafe acts were explored to identify those that could feasibly occur during access/egress of a WTG and substructure.
  - Large WTG diagrams were used to capture the location of potential unsafe acts and these were rated in terms of their relative significance.

Stage 2 Exercises

- Hazard risk analysis
  - Bow Tie analyses of the most significant hazards identified in Stage 1 were conducted using Bow Tie templates.
- Potential unsafe acts
  - Cause and Effect analyses of the most significant potential unsafe acts identified in Stage 1 was undertaken using Cause and Effect templates.
- Behavioural factors
  - 'Potential/theoretical' unsafe acts identified in Stage 1 were further explored and examined to determine the behavioural factors that lead to unsafe acts, identifying how these are currently controlled and developing ideas for improvement.

Each attendee participated in these exercises. At the end of the day the initial findings and conclusions were presented to the attendees in a plenary session, before concluding the workshop. The full findings and conclusions are presented in this report.

3.2 AGENDA

Workshop opening remarks

Frank Monaghan, Health and Safety Director, ScottishPower Renewables

Stage 1 exercise

- Hazard identification – Identification of hazards associated with access/egress
- Design issues identification – Identification of design issues causing the hazards associated with access/egress
- Unsafe acts identification – Identification of potential unsafe acts associated with access/egress

Stage 2 exercise – Introduction

- Hazard analysis (Bow Tie) – Analysis hazards/failure events (Facilitators: *Gordon Stewart* and *Conaill Soraghan*, ORE Catapult)
- Unsafe acts (cause and effect) – Analysis of the causes of unsafe acts (Facilitator: *Owen Murphy*, ORE Catapult)
- Behavioural factors – Identification and analysis of behavioural factors linked to unsafe acts (Facilitator: *Lynsey Duguid*, ORE Catapult)

Plenary session – Presentation on key findings/outputs from workshop

Andy Lewin, ORE Catapult

Closing remarks

Frank Monaghan, Health and Safety Director, ScottishPower Renewables

3.3 ATTENDANCE

Kerrie Forster	Acta Marine
Moritz Eggers	E.ON
Seb Godwin	E.ON
Kevin Tyrens	EDF
Andrew Sykes	Energy Institute
Celestia Godbehere	Energy Institute
Kate Harvey	Energy Institute
Lisa Mallon	GE
Trevor Johnson	HSE
Kevin Lennon	Innogy
Tua Collatz	MHI Vestas
Andy Lewin	ORE Catapult
Conaill Soraghan	ORE Catapult
Gordon Stewart	ORE Catapult
Lynsey Duguid	ORE Catapult
Owen Murphy	ORE Catapult
Karsten Bjerre Kristensen	Ørsted
Lars Askholm	Ørsted
Mark Jenkins	Siemens Gamesa
Andy Whitelaw	ScottishPower Renewables
Frank Monaghan	ScottishPower Renewables
Pat McCann	ScottishPower Renewables
Dan McKinley	SSE
Rich Sykes	Statoil
Martin Furth	Vattenfall

4 WORKSHOP STAGE 1 SUMMARIES

This stage of the workshop comprised three back to back exercises covering:

– Hazard identification – Identification of hazards associated with access/egress.
– Design issues identification – Identification of design issues causing the hazards associated with access/egress
– Unsafe acts identification – Identification of potential unsafe acts associated with access/egress.

The attendees were split into four groups and all attendees participated in these exercises, which were primarily data gathering activities. However, two specific recommendations were identified in this stage and are shown in this section:

Recommendations

– The perception of the groups was that there was a lack of adequate and suitable anchor points across the WTG fleet. It is recommended that work is undertaken to determine if this issue exists and if so, identify realistic improvement opportunities. This should be in the form of a recommendation report.
– Hatches across the WTG fleet were identified as a significant hazard and frustration for technicians due to many issues, including but not limited to: pinch points; poor quality or no dampeners; poor mounting points and latches; self-closing onto personnel; risk of being left open and a resultant fall from height etc. It is recommended that work is undertaken to identify realistic improvement opportunities. This should be in the form of a recommendation report.

Note – the full results and details of Stage 1 are presented in Annex 1.

5 WORKSHOP STAGE 2 SUMMARIES

This stage comprised three activities. A short summary of each is provided, followed by recommendations.

Exercise 2.1 – Hazard analysis (Bow Tie)

The purpose of a bow tie analysis is to investigate a top failure event that could occur from a hazard being realised.

In this exercise, three groups each completed one bow tie analysis. Three different hazards (and consequently three different failure events) were analysed and bow tie diagrams were created for the following:

– Hazard: Use of hatches. Failure event: hatch left open.
– Hazard: Working at height. Failure event: person falls from height.
– Hazard: Restricted and cluttered working environment. Failure event: slips, trips and falls.

Exercise 2.2 – Potential unsafe acts (cause and effect analysis)

The purpose of these cause and effect analyses was to explore the factors which contribute to potential unsafe acts.

In this exercise, three groups each completed one cause and effect analysis. Three different potential unsafe acts were analysed, and cause and effect diagrams were created for the following:

– Improper use of access systems.
– Poor communication.
– Poor housekeeping.

Exercise 2.3 – Behavioural factors (linked to unsafe acts)

This exercise further investigated and analysed five of the significant unsafe acts identified during Exercise 1.3 – Potential unsafe acts identification. These were:

– improper use of PPE;
– improper use of access systems;
– rushing;
– poor housekeeping, and
– poor communications.

The detailed discussions were centred around the behavioural factors associated with the unsafe act, current control measures, and what potential solutions could be implemented to improve the issue.

Recommendations

– Many of the causes of slips, trips and falls are mitigated by relatively simple good housekeeping and workplace organisation practices. Therefore, the G+ should explore the feasibility of producing good practice guidance on implementing the 5S methodology within the WTG working environment.

- It is recommended that the G+ creates an information sharing mechanism to facilitate the distribution of existing HAZID/HAZOP outputs. Additionally, that good practice for undertaking these risk analysis activities is identified and a common set of templates and guidance is created.
- Many unsafe acts could be attributed to technicians having to adapt how they perform activities due to the design of the WTG and/or associated components and equipment. There is also a perception that the users are not being adequately considered during the design stage. It is recommended that as an industry, a formal, robust and consistent feedback loop is implemented between users (technicians) and designers.
- There can be significant variance in the toolbox talk/pre-sail brief delivered to or received by offshore technicians. It is recommended that G+ investigates the feasibility of producing good practice guidance on how to prepare and deliver an effective toolbox talk/pre-sail brief.
- The G+ should consider a benchmarking study to identify good practice of tools/equipment inventory and tracking systems used across member organisations, and any near future innovations being considered. The study could also highlight the benefits of how new technology helps organisations track their equipment to ensure that the right tool is available for each job without teams having to carry several duplicates.
- Supervisory leadership in safety culture and behaviours is perceived to be varied and those being promoted into supervisory roles could be supported better to aid the transition. A review across G+ member organisations is recommended to establish whether any programmes currently exist within individual organisations which assist good technical staff to make the transition to supervisory positions. If good practice is available it should be shared, and if not then the feasibility of enabling this should be considered.

Note – the full results and details of this stage are shown in Annex 1.

ANNEX 1
DETAILED WORKSHOP NOTES

A.1 WORKSHOP STAGE 1 EXERCISES

Purpose

The purpose of this stage of the workshop was to firstly identify the hazards associated with access/egress of a WTG and substructure. Secondly, the purpose was to determine the design issues causing the hazards, the control measures in place, and any improvement ideas. Lastly, to identify potential unsafe acts associated with access/egress, which together with the hazards, would feed into Stage 2 of the workshop for further analysis.

Outputs

The HAZID was conducted using large WTG diagrams. The hazards identified by the attendees were captured on pre-prepared Post-it notes with the headings 'what' (is the hazard), 'where' (on the turbine would it be realised) and 'why' (it is a hazard). An example of the WTG diagram showing a selection of the hazards identified is shown in Figure A.1, and Table A.1 lists all the hazards identified.

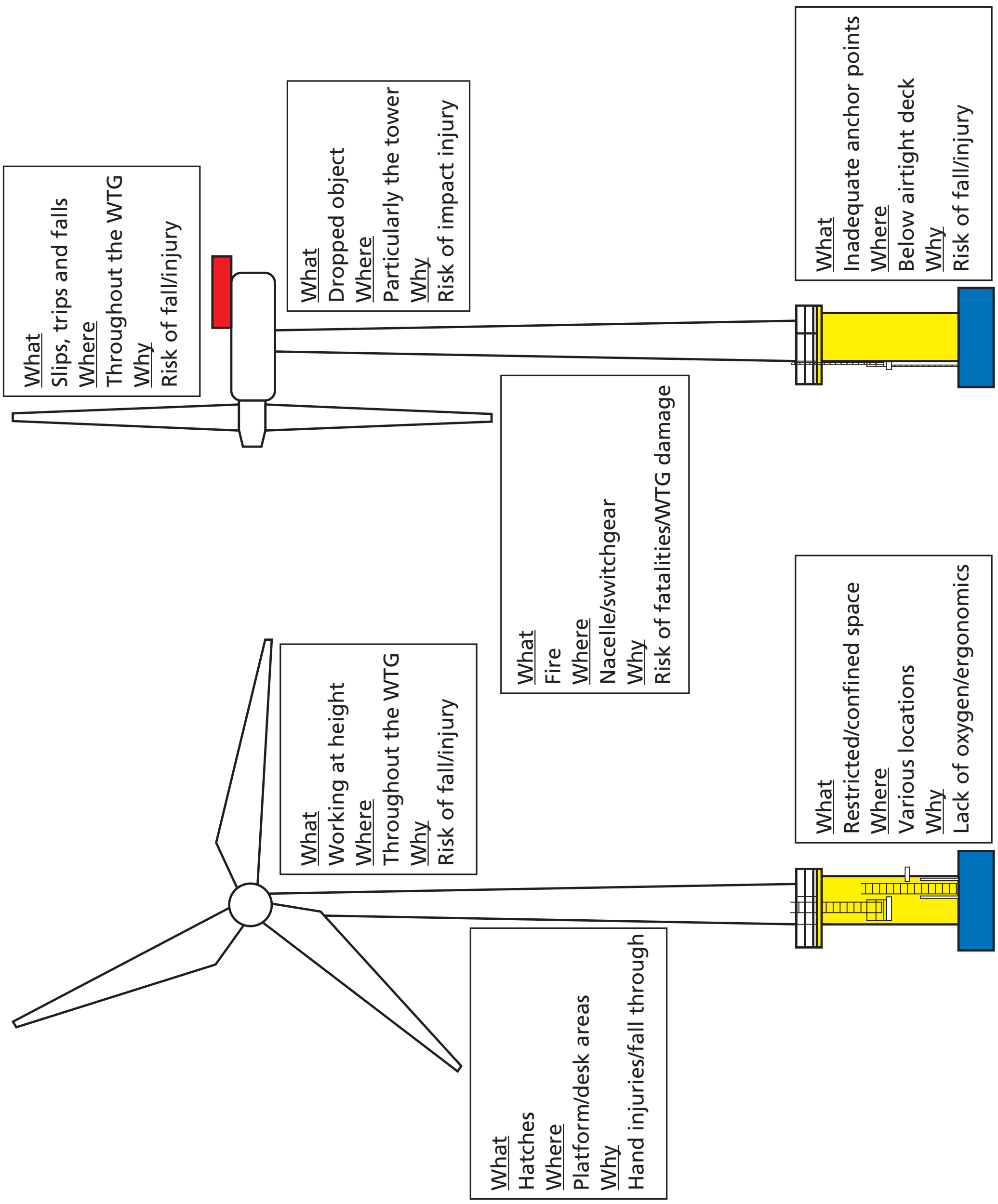


Figure A.1: Hazards and their location

Table A.1: HAZID

Hazard	Location on WTG	Reason it is perceived as a hazard
Dropped object	Various locations, especially in the tower	– Dropped objects with the potential to cause injury to persons both outside and within the WTG are well known and documented in the industry
Inadequate anchor points	Various locations but biggest issue below the airtight deck and evacuations from lifts	– Increased risk of falls from height – Increased difficulties during emergency evacuations – Ergonomic/musculoskeletal issues
Restricted/ confined space	Below the airtight deck, the hub, nacelle and in blades	– Potentially a lack of breathable air – Overheating – Small spaces to squeeze through – Ergonomic/musculoskeletal issues – Slips, trips, falls and bumps
Escape from nacelle	The nacelle	– Difficulty in egressing the nacelle quickly and safely in the event of an emergency
Slips, trips and falls	All locations	– These are well recognised and common hazards that cause injury
Hatches	Various locations e.g. on platforms, to yaw deck and to nacelle	– Injury to persons through closing on hands – Potential to fall through – Dropped object to fall through onto persons below
Work at height (various locations in WTG)	Various, especially below the airtight deck and between the yaw-deck and the nacelle	– Injuries/fatalities resulting from a fall from height
Machinery (moving parts)	Particularly the service lift and in the nacelle	– Various types of machine related injuries (e.g. crushing, entanglement) and potential fatalities
Fire	Particularly the nacelle and base of tower (switchgear)	– Potential of multiple injuries/ fatalities – Extensive damage to WTG
H_2S gas build-up	Moon pool and transition piece	– Wide range of health effects including death
General maintenance activities	All locations	– The need to have a technician performing these activities exposes them to many other hazards identified here
Poor quality/ damaged PPE	All locations	– May fail when relied upon, leading to injury or even a fatality

Table A.1: HAZID (continued)

Hazard	Location on WTG	Reason it is perceived as a hazard
Manual handling (tools/ equipment)	Particularly the nacelle	– Well known musculoskeletal injuries/conditions from manual handling
HV/LV Electricity	Particularly the nacelle and base of tower (switchgear)	– Risk of electric shock – Burns – Fire

Following the HAZID, a selection of the significant hazards chosen by the attendees was explored further to identify the design issues that caused these hazards. The current control measures in place were also captured in addition to any potential solutions/improvement ideas to address these design issues/hazards. The output from this is shown in Table A:2.

Table A.2: Design issues associated with hazards

Hazard	Design issue that causes hazard	Current control measures	Potential solutions/ improvement ideas
Dropped object	– Gaps in hatches – Hatch lock fails – Loose bolts from coolers – Other bolts/grease caps Cooler panels coming loose – General equipment and components being removed for maintenance activities – Panels from helipad – Designs focus on the WTG itself not the persons who will be inside	– Good housekeeping – Exclusion zones – One person on ladder at a time – Closing hatches – Plate to cover gaps	– Toe boards around hatches – Better materials and maintenance of lock and hatch dampening – Anchor point situated above evacuating hatch – Design equipment where bolts don’t need to be tightened – Use of robotic tools – Increase condition monitoring from onshore e.g. SCADA systems – Include redundancy into equipment to prevent loose parts – Fix netting in area between handrails and other appropriate locations – Implement robust feedback loop from technicians to designers – Sharing of good practice/lessons learned

Table A.2: Design issues associated with hazards (continued)

Hazard	Design issue that causes hazard	Current control measures	Potential solutions/ improvement ideas
Inadequate anchor points	– Lack of anchor points where needed including only one for lift evacuation and more than one may be in the lift – Lack of standardisation e.g. different styles, colours and types of anchor points – Lack of standardisation across fleet of lifts for emergency evacuation – Wrong placement – Poor ergonomics required to use – Designed more for access and not egress	– Retrofitted yo-yos – Different types of evacuation equipment and additional accessories	– Redesign anchor points and placement – Reassessment required to understand users' requirements and what else can be used in the turbine as an anchor point
Restricted/ confined space	– Maintenance/ inspections required below airtight hatch – Inside blades and hubs – Lack of space between ladder and tower wall – Small hatches – Hub hatch trapping people inside – Location of components – Cost driving design decisions – More people working on turbine than space realistically allows	– Assisted climb systems – Manual handling aids e.g. hoists	– Redesign/reassessment of equipment and number of personnel in nacelle – Fixed toolbox in nacelle – Eliminate/reduce need for technicians to be in the hub – Evaluate longer-term savings of designing in WTG specifications that reduce requirement for technician O&M visits – Consider rescue from tight areas first
Escape from nacelle	– Not designed for persons/injured persons – Insufficient number of high anchor points – No clear level pathway – Smoke and heat from below quickly travel to nacelle	– Training – ERP – Defined escape routes – Drills – Place of refuge	– Single level and wide walkways

Table A.2: Design issues associated with hazards (continued)

Hazard	Design issue that causes hazard	Current control measures	Potential solutions/ improvement ideas
Slips, trips and falls	– Short ladders – Steep stairs with no fall protection – Different heights between stair steps – Poor handrails – Reliance on grip tape – Insufficient stepping platforms – Dirty areas contaminated with grease/lubricants – Drip trays and bunding insufficient – Frost/ice/wet surfaces – Steep angled surfaces – Planned maintenance tasks in poor locations – Design of space not helpful for rescue – Inadequate illumination – Moving yaw deck – Definitions not clearly understood/ defined i.e. restricted/ confined space	– Grip tape	– Sealed grease and lubricant units (like a car) – Create proper stepping platforms not just what's there – Retrofit drip trays and review designs – Put more thought and consideration into reach/use of cleaning tools
Hatches	– Pinch points – Poor quality dampeners or none at all – Poor mounting points and latches – Self-closing onto personnel – Risk of being left open and fall from height – Small and ergonomically poor to access/egress	– Fluorescent tape – Illumination – Manual control of hatches – Procedures	– Lightweight hatches – Soft closing – Self-opening and closing – Design a space between hatch and edge – Better quality dampeners – More robust mounting points and latches – Warning light/alarm if hatch not closed – Obtain feedback from technicians and redesign to suit users

Table A.2: Design issues associated with hazards (continued)

Hazard	Design issue that causes hazard	Current control measures	Potential solutions/ improvement ideas
Work at height (various locations)	– Poor locations for items that need technician attention – Need for continuous protection from a fall throughout access activities – No standardised provision for fall arrest system – No fall arrest system in place below airtight hatch in monopiles – Poor design for emergency evacuation and getting casualty from below airtight hatch – Limited space to fit fall arrest system or none in yaw deck to nacelle ladder – Ladder not fixed in yaw deck (needs to rotate) – Yaw deck/nacelle hatch location not ideal – Ladders may not be reinforced where needed for rescue purposes – Failure of handrails e.g. rusting	– PPE – Work at height guidelines – HSG – Double hooking – Rope access – ERPs – Procedures – RAMS	– Should design out the need to work from height – Move components to more accessible locations – Guidelines being reviewed – Climb assists – G+ ladder climbing workstream – Standard anchor points for yo-yo system – Reinforced ladders and handrails – Impact absorbing floor material
H_2S gas build-up (moon pool and TP)	– Design of anti-corrosion system and sea water – Airtight hatches and other seals leaking – Poor venting systems	– Ventilation – Airtight seals	– Better design of monopiles – Better venting and monitoring – Learn from oil and gas industry

Table A.2: Design issues associated with hazards (continued)

Hazard	Design issue that causes hazard	Current control measures	Potential solutions/ improvement ideas
Machinery–moving parts	– Collisions with persons climbing if ladder mounted – Interaction of the moving parts with the tower – Cluttered layout and short of space e.g. nacelle	– Guards, protection and barriers – Interlocking – Reduced exposure to moving parts	– Redesign machinery layout – Make lift inoperable if person on ladder – 'Hotel' type lift
Fire	– Inadequate prevention – Locked doors e.g. tower door	– One hand push bars (retrofit) – Inert gas protection for cabinets	– Safer electrical components – Engineering to reduce fire risk
General maintenance activities	– Design consideration not conducive to performing maintenance activities	– Procedures – RAMS – Toolbox talks – Supervision	– Full consideration of maintenance ergonomics at design phase

The last exercise in Stage 1 was the identification of potential unsafe acts associated with access/egress of a WTG. The potential unsafe acts identified by the attendees were captured on pre-prepared Post-it notes with the headings 'what' (is the potential unsafe act), 'where' (on the turbine would it likely occur) and 'why' (the motivation for committing an unsafe act). An example of the WTG diagram showing a selection of the unsafe acts identified is shown in Figure A.2 and Table A.3 lists all the unsafe acts identified.

Table A.3: Potential unsafe acts identification

Unsafe act	Location on WTG	Why (motivation behind an unsafe act)
Not wearing PFPE	Nacelle/hub	– Perceived low risk versus time trade off – Become too warm and uncomfortable wearing it – Not able to feel equipment through gloves – A hassle to carry PPE equipment into nacelle – Inadequate training
Not installing pitch locks	Hub	– Heavy – Time consuming – Perceived as not necessary

Table A.3: Potential unsafe acts identification (continued)

Unsafe act	Location on WTG	Why (motivation behind an unsafe act)
Not connecting to fall arrest systems	Tower/between platforms	– Confidence in climbing ability and perceived low risk – Quicker to climb – Equipment difficult to use or damaged
More than one person on access ladder at same time	WTG access ladder	– Confidence in climbing ability and perceived low risk
Not hooking on	Top deck/nacelle	– PPE removed to work more comfortably in the nacelle – Complacency – Lack of suitable anchor points
Leaving hatches open	Throughout WTG	– Ease of access and annoyance with repeatedly having to open/close – Easier when transporting tools – Easier to communicate with colleagues
Not maintaining three points of contact when ladder climbing	Tower	– Complacency – Relying on fall arrest system using the WTG tower
Misuse of service lift e.g. riding on top/using as a work platform	Tower	– Perceived as low risk – Convenient to do so – Easy to bypass operating parameters so it can carry heavier components for example
Opening/working on electrical cabinets whilst still live	Various control panel locations	– Quicker and easy to bypass isolators
Misuse of PPE	Throughout WTG	– Inadequate training – Easier to do job – Equipment difficult to use or damaged – Equipment easier to use the wrong way
Unnecessary climbing	Tower	– Lack of trust in service lifts
Inappropriate manual handling	Throughout WTG	– Speed of task – Slow and time consuming to obtain appropriate manual handling aids – Macho culture
Pressing 'wrong' buttons on control panels	Various control panel locations	– Poor design, labelling and ergonomics within control panels – Easy to make an unintentional selection and not notice

Table A.3: Potential unsafe acts identification (continued)

Unsafe act	Location on WTG	Why (motivation behind an unsafe act)
Working on/near rotating unguarded machinery	Nacelle	– To get the job done quickly – Overconfidence
Using wrong tool	Throughout WTG	– Lack of planning – A hassle of more access/egress to get the right tool – It's quicker to use an inferior substitute
Carrying tools	Tower ladders	– To save time especially if been delayed by other factors
Not securing tools	Throughout WTG, especially work areas	– Securing not available or suitable – Complacency and low risk perception
Blocking access/egress routes	Nacelle	– Lack of alternative options – More equipment than the restricted space can easily accommodate
Poor housekeeping	Throughout WTG, especially work areas	– Time pressures – Tardiness – Poor culture
Defeating safety features and interlocks	Throughout WTG	– To save time especially if been delayed by other factors – Poor appreciation of interlock necessity
Not following procedures	Throughout WTG	– Time pressures – Procedures can be long and over laborious to read and follow – Technicians have found 'better/ quicker' ways of doing job that they also perceive as being safe

Analysis and findings

The HAZID allowed identification of the hazards that would be explored in more detail during the Stage 2 exercises. There were numerous hazards identified and these were not clustered in one location but across the WTG. However, areas such as below the airtight deck, from the yaw deck to the nacelle, and tower platforms with hatches left open were highlighted as areas where there was a risk of falling when working at height.

Exploring some of the design issues that caused the hazards allowed an understanding of what they are, how they are currently controlled and importantly, ideas for improvement to be generated.

The potential unsafe acts identification activity generated a list of potential unsafe acts that would be explored in more detail during the Stage 2 exercises. Like the HAZID, there were numerous and varied unsafe acts identified and these were not clustered in one location but across the WTG. However, areas such as the tower and the nacelle accounted for most.

Two recommendations were developed during the analysis of the design issues hazard:

Recommendations

- The perception of the groups was that there was a lack of adequate and suitable anchor points across the WTG fleet. It is recommended that work is undertaken to determine if this issue exists and if so, identify realistic improvement opportunities. This should be in the form of a recommendation report.
- Hatches across the WTG fleet were identified as a significant hazard and frustration for technicians due to many issues, including but not limited to: pinch points; poor quality/no dampeners; poor mounting points and latches; self-closing onto personnel; risk of being left open and resultant fall from height etc. It is recommended that work is undertaken to identify realistic improvement opportunities. This should be in the form of a recommendation report.

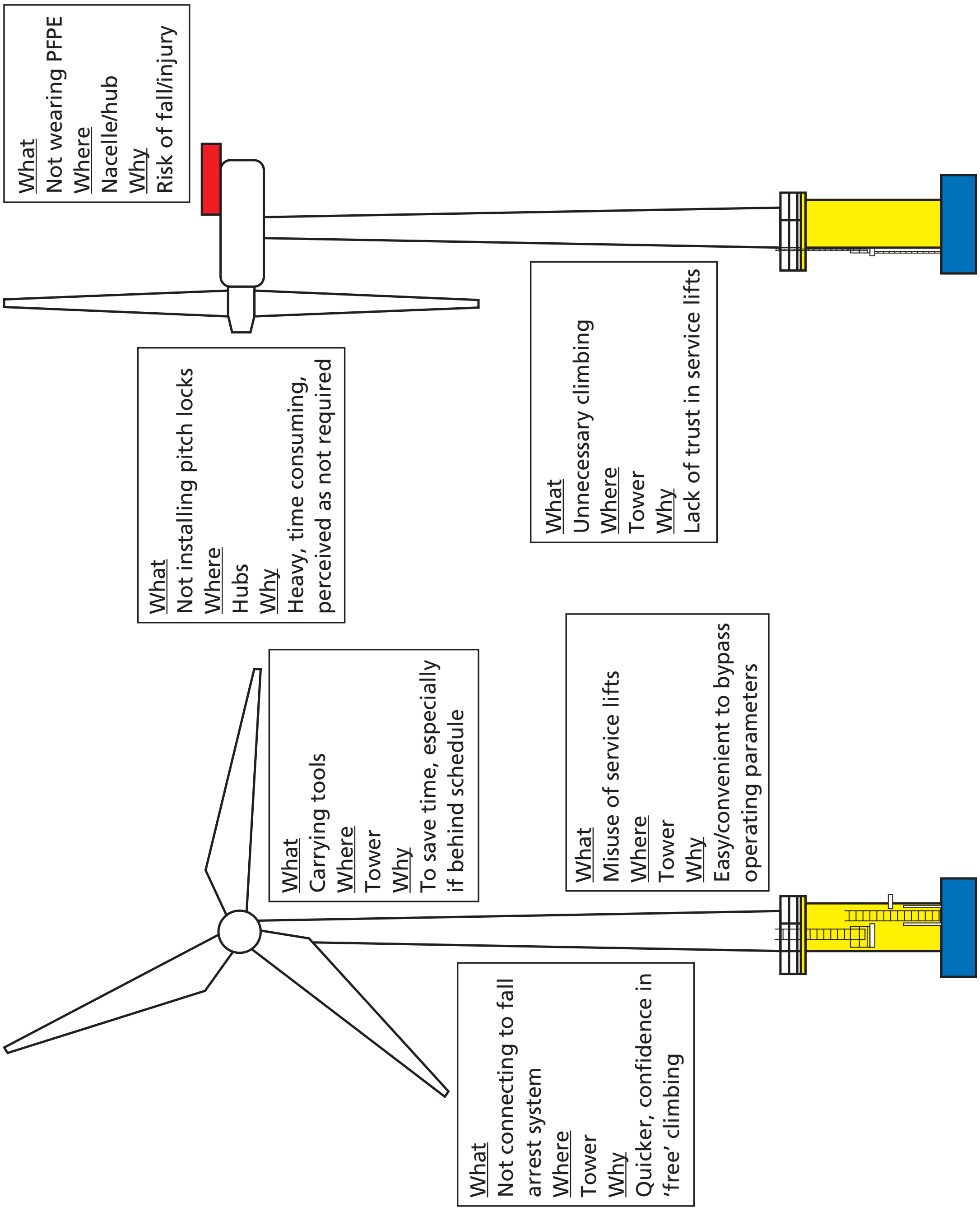


Figure A.2: Potential unsafe acts and their location

A.2 WORKSHOP STAGE 2 EXERCISES

A.2.1 Exercise 2.1 hazard analysis (Bow Tie)

Purpose

The purpose of a bow tie analysis is to investigate a top failure event that could occur from a hazard being realised. The groups were provided with the top failure event for one of the most significant access and egress hazards (established in the Stage 1 sessions). The groups brainstormed the threats (that can cause the failure event to happen), consequences (which can result from the failure event occurring) and the controls and mitigations. These details were captured on a wall mounted bow tie template.

Outputs

Three groups completed one bow tie diagram each and each group analysed a different hazard and top failure event.

Bow tie diagrams were created for the following:

- Hazard: Use of hatches. Failure event: Hatch left open.
- Hazard: Working at height. Failure event: Person falls from height.
- Hazard: Restricted and cluttered working environment. Failure event: Slips, trips and falls.

The bow tie diagrams are shown in Figures A.3–A.5.

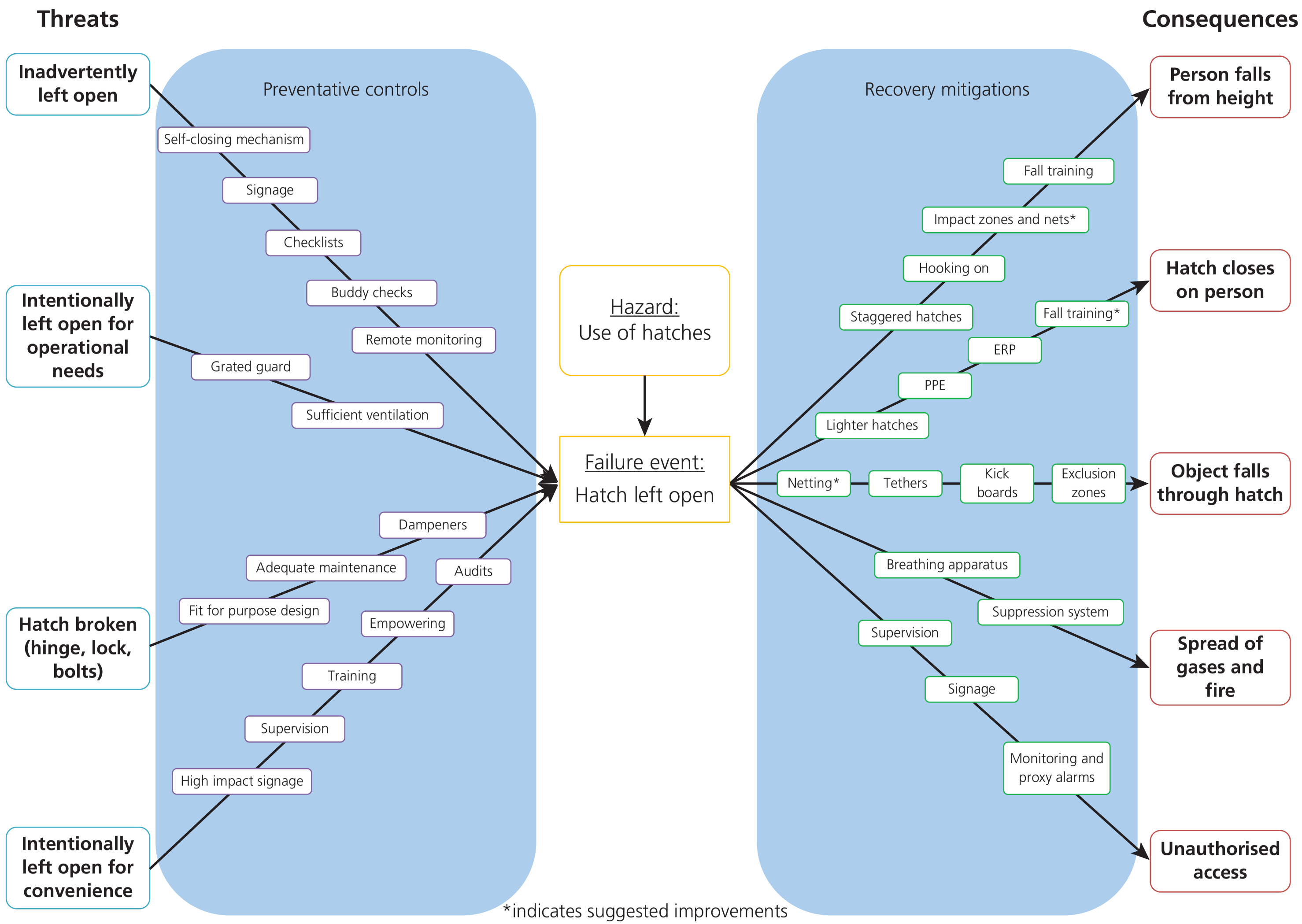
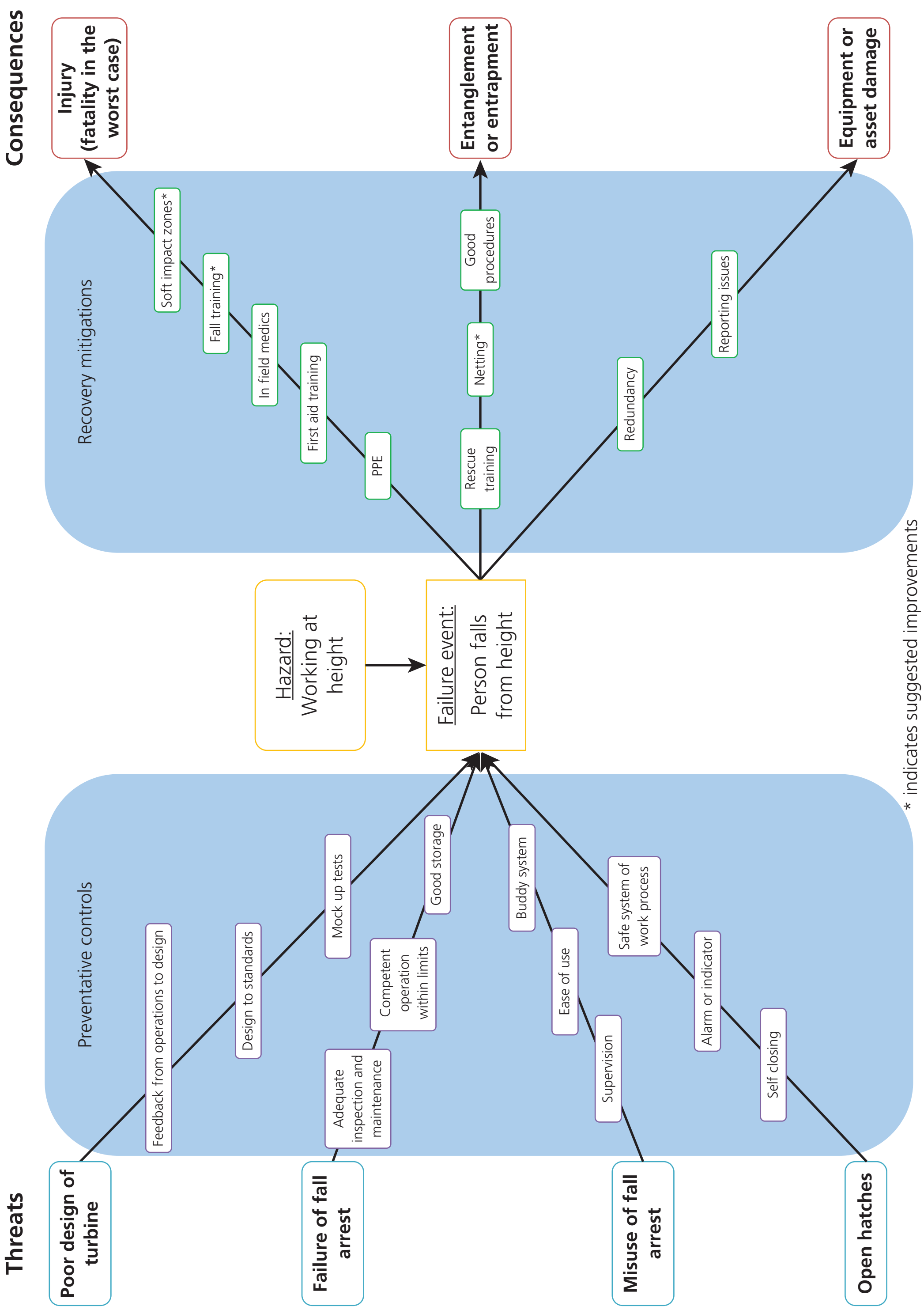


Figure A.3: Use of hatches Bow Tie



* indicates suggested improvements

Figure A.4: Working at height Bow Tie

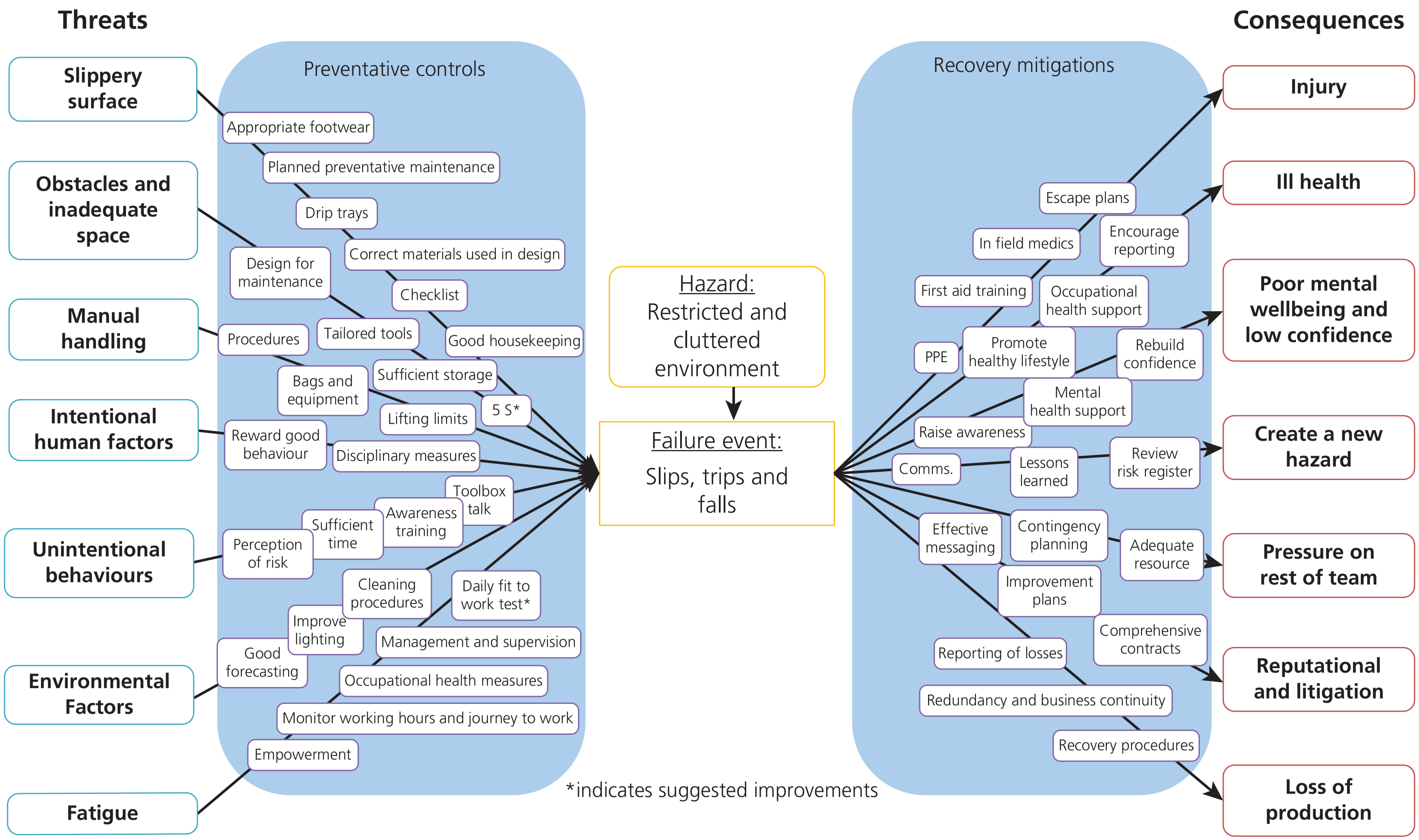


Figure A.5: Restricted and cluttered working environment Bow Tie

Analysis and findings

The bow tie diagrams clearly illustrate the discussion areas for each failure event. The bullet points in this section focus on the potential improvements that were recorded.

Hazard: Use of hatches. **Failure event:** Hatch left open

- There was general agreement that simple but targeted signage would have high impact. In particular, signs should be on the hatches instead of on notice boards in O&M bases. One useful idea was to colour code hatches, so it is clear which hatches are more likely to lead to top failure events such as injury to persons.
- A technical solution could be to apply acoustic indicators that would go off after a sufficient period has elapsed for the intended use of the hatch. However, a downside could be additional cost/maintenance associated with such devices.
- A discussion took place about the failure modes and mechanisms related to hatches. Typically, the dampers are being forced so the hatch closes quicker. This can cause the hinge attaching the hatch to the turbine to come loose and the bolts to unscrew. Often the locking mechanism breaks so the hatch will not stay closed. These potential issues should be factored into inspection regimes.
- A commonly suggested solution to mitigate the impact of a person or object falling through a hatch would be to stagger hatches, reducing the distance a person or object could fall. Furthermore, netting or softer impact zones could mitigate consequences. However, these mitigations themselves will also present new issues and potential risks. Whilst staggering hatches would reduce the potential fall distance, it would also result in multiple attachments to a fall arrest system, thus increasing effort and time to climb the tower. Also, the distances between tower levels may still leave a sufficient distance for severe if not potentially fatal fall distances. Softer impact zones would potentially not mitigate injuries due to the fall distance and there would be potentially be an increased risk of slips, trips and falls and fire loading of the WTG. If netting were introduced, it would have to be unattached and attached at every point and would also have to be tensioned onto hard points.

Hazard: Working at height. **Failure event:** Person falls from height

- All wind turbine manufacturers should have a longer-term goal to design out the need for personnel to be working at height. However, for the O&M of existing and current next generation turbine models, it is inevitable that technicians will continue to work at height.
- Wind turbine designers require feedback from the operational phase and some form of mock-up test would be beneficial to explore operational issues before a turbine model is wholescale manufactured.
- It is critical that all fall arrest systems are adequately inspected and maintained and are only operated within design limits.
- A suggestion was made to expand the scope of rescue training to include some form of fall training. This would provide guidance for how to fall and land in such a way as to minimise injury. If this were to be implemented care would need to be taken as this may be interpreted by those on the training course that they are expecting to fall at some point during climbing activity. Also, due to the action of climbing a ladder a fall is unexpected, and by the very nature of a fall from a ladder backwards would potentially not allow sufficient time for a technician to react.

Hazard: Restricted and cluttered working environment. **Failure event:** Slips, trips and falls

- Many of the threats causing slips, trips and falls are mitigated by relatively simple good housekeeping practices. It would therefore be beneficial to adopt the 5S workplace organisation methodology for the WTG working environment.
- Another common threat is that technicians are suffering from fatigue, tiredness or other symptoms and do not alert anyone. This could be addressed with a daily 'fit for work' check or a brief call to the control centre before transit from a vessel or helicopter to turbine.
- The impact of a slip, trip or fall can be much longer-term than the initial injury. It can lead to other issues such as poor mental health, wellbeing and lack of confidence. These are relatively immature concepts for the industry, so it is important that site owners focus on raising awareness of these issues and empower technicians to discuss and report issues.

– *General findings*
  - It was noted that some organisations have done or conduct bow tie analyses and other activities e.g. HAZID and HAZOP, regularly (typically when there are weather affected days). These participants could be willing to share these learnings and resources; however, a mechanism is required to facilitate this information sharing effectively.
  - There is significant value in going through the process of conducting risk analysis such as the bow tie analysis, as it shares ideas and encourages critical thinking. Templates and exercise guidelines should be developed by the G+.
  - Completing three bow tie analyses on different failure events has revealed that it is important to be very focused in terms of the failure event. Otherwise, it is likely that the output will be extremely broad in nature and lack the detail required to land on tangible improvement suggestions. Furthermore, the most practical input came from participants with recent and regular site based experience. It is critical that these exercises include the views from such personnel to extract impactful improvement suggestions.

Recommendations

- Many of the causes of slips, trips and falls are mitigated by relatively simple good housekeeping and workplace organisation practices. Therefore, the G+ should explore the feasibility of adopting and implementing the 5S methodology within the WTG working environment.
- It is recommended that the G+ creates an information sharing mechanism to facilitate the distribution of existing HAZID/HAZOP outputs. Additionally, that good practice for undertaking these risk analysis activities is identified and a common set of templates and guidance is created.

A.2.2 Exercise 2.2 Potential unsafe acts (cause and effect analysis)

Purpose

The purpose of the cause and effect analysis was to investigate in a structured way the factors which could lead to a potentially unsafe act occurring.

Three separate groups analysed a single unsafe act each. The potential unsafe acts analysed were those described as highest priority by the Stage 1 hazard identification exercises. The groups analysed factors which could contribute to a potential unsafe act by considering contributing factors. Contributing factors were grouped under six categories (Method, Person (Man), Machinery, Materials, Mother Nature, and Maintenance). When a contributing factor was identified the group were also asked, where possible, by further questioning to describe why the factor identified would lead to a potentially unsafe act.

Outputs

Three groups completed one cause and effect diagram each. The unsafe acts analysed by the workshop sessions were:

- Improper use of access systems (e.g. hatches and gates).
- Poor communication.
- Poor housekeeping.

The cause and effect diagrams are shown in Figures A.6–A.8.

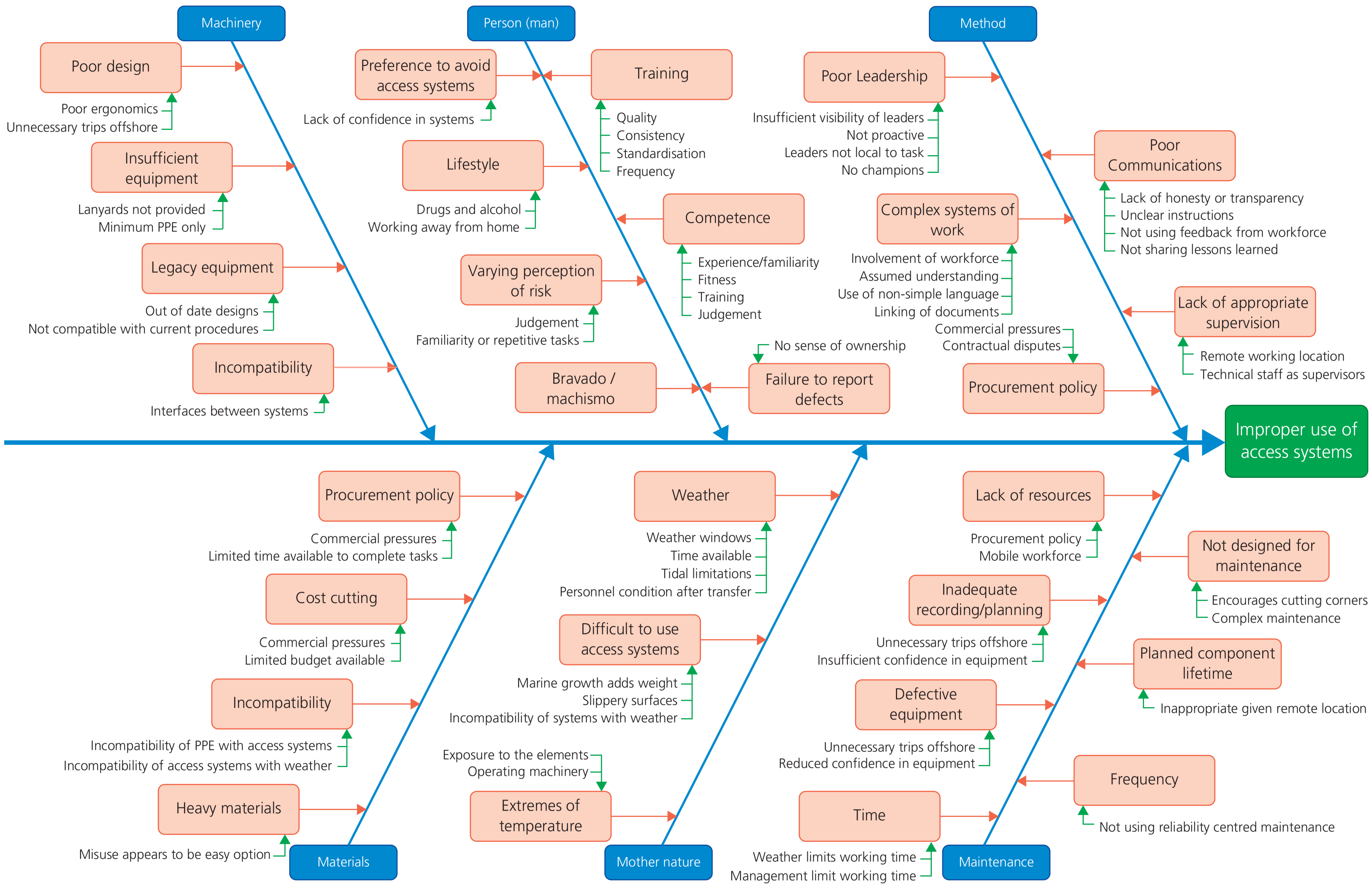


Figure A.6: Improper use of access systems

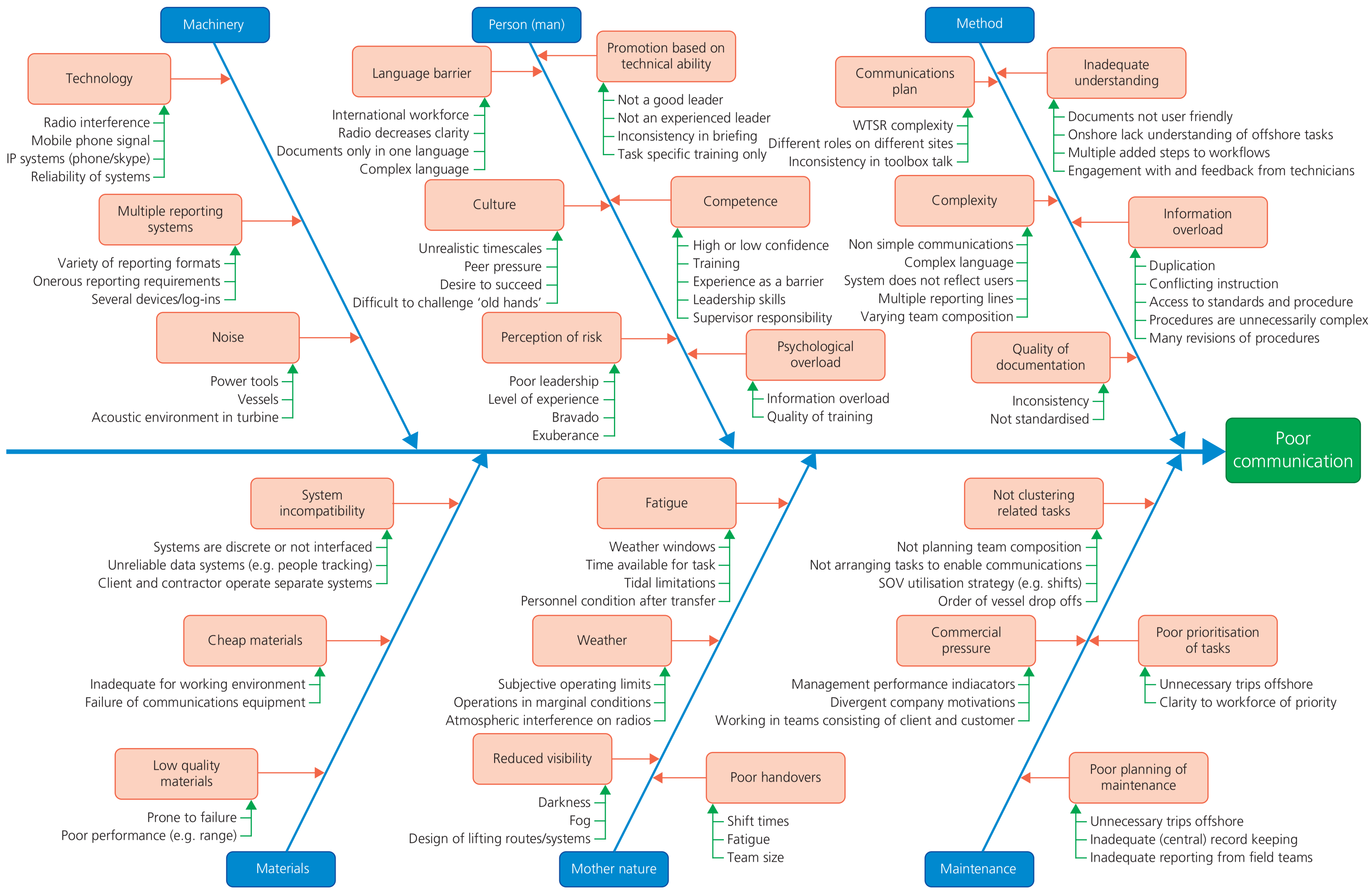


Figure A.7: Poor communication

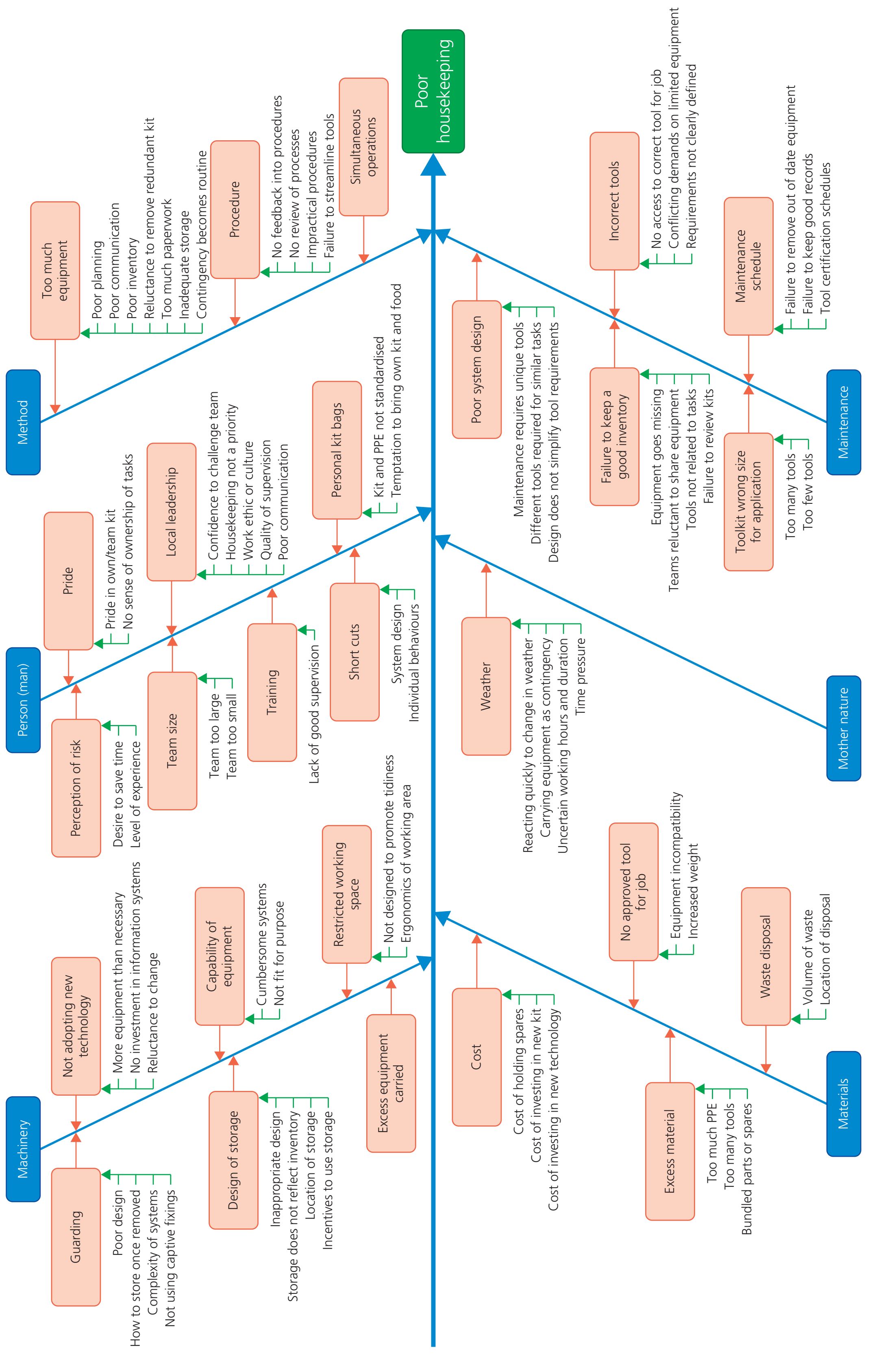


Figure A.8: Poor housekeeping

Analysis and findings

Despite focusing on different potential unsafe acts, certain key themes were present during the discussion in each group. Challenges described by at least two and often all three of the groups conducting this exercise included:

– *Leadership:* many unsafe acts had an ultimate cause linked in some way to the competence or visibility of local leadership. Many participants described the promotion of good technical staff into supervisory roles, a transition which is not unique to the offshore wind industry in being challenging to make. Training and development opportunities focusing on the soft skills required to complement the routine technical education was thought to be an opportunity to improve the culture and behaviours of staff.
– *Planning:* particularly for the planned (rather than reactive) element of any offshore work, the workshops all identified an opportunity to improve the way that tasks are planned. It was suggested that better record keeping and proactive planning would have the potential to reduce unplanned trips offshore, significantly reducing exposure to situations which can drive unsafe acts.
– *Weather:* offshore wind operations are inherently sensitive to weather. Weather was described by the groups as a source of uncertainty, which could drive rash or incomplete decision making, skew the judgement of acceptable risk by site staff and generally be a source of pressure requiring careful management.
– *Complexity:* there exists significant complexity in the procedures used by those working offshore. Procedures may be difficult to access and/or understand, with the linking of documents an example of unhelpful practices. The tendency to increase the complexity in procedures as a response to hazards was also described as having the potential to contribute to unsafe acts. It was suggested that the opportunity for those tasked with following procedures to participate in their drafting and review would be likely to reduce the potential motivations for unsafe acts, as procedures would be clearer and technicians would feel more invested as a result of being engaged in the process.

Alongside the general themes described, noteworthy findings of this workshop were:

Improper use of access systems

– The level of experience of an individual or team may influence unsafe acts. A sentiment was expressed that a turbine technician is perceived as a 'macho' role, and that, particularly when incentivised to troubleshoot and return a generating asset to production quickly, the perception of risk may be skewed and tendency towards unsafe acts may be high. Similarly, inexperienced personnel may inadvertently perform unsafe acts as a result of a lack of familiarity with a particular access system, or they may not feel comfortable challenging the behaviour of those perceived to be more experienced.
– Access systems which were perceived as being of low quality and/or time consuming to use were thought likely to drive unsafe acts, such as avoidance, defeat or misuse.
– The influence of time pressures, most specifically those generated by limited weather windows or situations which change rapidly in response to weather, were discussed in this workshop. It was thought that both the condition of a technician after a vessel transit and the pressure to complete work in the time available may drive unsafe acts in the use or misuse of access systems.

Poor communication

- Use of several discrete systems was described as having the potential to contribute to unsafe acts through poor communication. The requirement to use several means of reporting, and the potential compatibility of systems with each other was discussed. For example it may be attractive to reduce paperwork by moving to IT systems to record activities, but in the event that such systems are perceived to be unreliable by workers it may complicate the reporting and communication landscape by keeping an element on paper and some online.
- As in the previous section, the complexity of procedures was described as having the potential to drive unsafe acts. Technicians may have insufficient access, be overloaded with information or see conflicting rules around reporting and communication behaviours between sites.
- Commercial or contractual barriers were identified as having the potential to drive unsafe acts related to communications. Primarily this would manifest as a result of reluctance to share information or report across company boundaries, a challenge which may be most significant when an offshore team comprises staff from supplier and customer organisations which may not be incentivised, or feel able, to talk freely or share documentation.

Poor housekeeping

- These groups established that it is commonly the case that far more equipment than is required for the task at hand is carried to the working location on an offshore turbine. By way of example, duplication and excess in the toolkits carried can lead to clutter in often restricted working spaces. Similarly, the remote nature of the location of work may encourage an excess of 'contingency' equipment. A notable example was the carrying of a defibrillator by each team, when perhaps offshore storage would be more appropriate.
- The ability of modern technology to help to reduce the clutter and hence improve housekeeping was described during this workshop. Solutions to the problem of having both too many or the incorrect tools and materials for a task may include a move to data systems which can reduce the amount of physical paperwork carried, and/or improve inventory and tracking of tools and equipment to ensure that the right tools are in the right place, and potentially a linking of service tasks to the tools required.
- Unsafe behaviours relating to the temptation for technicians to bring excessive personal kit and supplies were also described.

Recommendations

Improper use of access systems

- It is recommended that an opportunity for improvement exists in the development of supervisors as leaders and champions of safe behaviour. A review across G+ member organisations may help to establish whether any programmes currently exist within individual organisations with the aim of helping good technical staff to make the transition to supervisory positions.
- It was established during this and other exercises that time pressures can contribute to unsafe acts. It may be beneficial to share understanding between G+ member organisations about good practice in reducing the likelihood of both commercial and weather driven pressures which may encourage unsafe acts. How do the best in the industry at safety ensure that staff are not inadvertently incentivised to

take unacceptable risks? Could others learn what has been found to work in the promotion of safe behaviour?

Poor communications

- It was suggested that there can be significant variance in the toolbox talk or pre-sail brief delivered to or received by offshore technicians. The quality of such briefings may be influenced by the competence of the presenter, quality of the task planning, and also by variances in process from site to site. It is recommended that G+ investigates the feasibility of producing some good practice guidance on how to prepare and deliver an effective toolbox talk. This could serve to both increase the quality and also to add consistency to the experience of technicians who work on a variety of sites.
- The complexity of procedures was described in this and other workshops. It is possible for technicians to be exposed to too much or too little written information, for example in the form of procedures. Where possible, those involved with conducting the work should be involved in the drafting and review of procedures and processes which define work scope. This may have the benefit of both focusing procedures on what information is actually required, and also of increasing the engagement of the workforce.

Poor housekeeping

- A dominant theme during this workshop was the tendency to take too much equipment offshore. Drivers included:
  - Not having a well inventoried or suitably focused toolkit for a certain well defined (e.g. service) task.
  - A reluctance to reduce equipment carried as contingency.
  - The influence of uncertain working conditions and time leading to the transfer of excessive amounts of personal equipment and food at the start and end of each working shift.
- It is recommended that good practice in provision of offshore contingency equipment (e.g. emergency rations) and perhaps also in how to manage an appropriate amount of personal equipment (the provision of a standardised personal bag was mentioned) be shared between G+ member organisations.
- The G+ may also wish to consider a benchmarking of the inventory and tracking of tools and equipment across member organisations in order to identify any technological or process innovations which could give improvement by reducing clutter. The focus of this exercise could be to highlight how new technology helps organisations to track their equipment to ensure that the right tool is available for each job without teams having to carry several duplicates.

A.2.3 Exercise 2.3 Behavioural factors (linked to potential unsafe acts)

Purpose

The purpose of this exercise was to uncover the behavioural factors associated with the five most important unsafe acts resulting from exercise 1. Focus was also given to discussing current control measures and potential improvements which could be made to change these behaviours and reduce the likelihood of the unsafe acts occurring.

Outputs

See Table A.4.

Table A.4: Behavioural factors linked to unsafe acts

Unsafe act	Behavioural factors	Current control measures	Potential solutions/ improvement ideas
Improper use of PPE (e.g. clipping on/fall arrest systems/work positioning etc.)	– It's considered a nuisance – Perception that risk is low (big issue) – Speed – Rushing to get finished – Violation of procedures – Pressure to get job done – Complacency ('nothing bad has happened yet') – Misunderstanding – Swapping of PPE between personnel – Attitude – not interested – Changes to routine situations can mean PPE no longer suitable – Lack of training – Compatibility of equipment and anchor points – technician may clip onto alternative point – Lack of anchor points – Equipment usability – 'path of least resistance'	– Training and renewal – Safe systems of work (procedures) – Supervision – Buddy checks – Audits – Positive reporting culture allows people to intervene/ challenge – Information available regarding risks	– Buddy system not used as much during time on turbine – mostly just for initial checks of harness etc. Could implement use of buddy checks whilst moving around turbine – Better training for when on turbine – Compare to other industries (as well as other organisations within same industry) to consider others' working from heights practices – Higher level responsibility – Feedback issues to designers – Training from equipment manufacturers themselves – More regular training refreshers – Aim to design out the need for PPE

Table A.4: Behavioural factors linked to unsafe acts (continued)

Unsafe act	Behavioural factors	Current control measures	Potential solutions/ improvement ideas
	– 'I can get away with it' attitude – No reward for good behaviour – Embedded poor practice passed on – the norm – Macho culture – Don't want to slow team down		– Supply PPE with better interfaces/ more suitable (and it needs to suit individuals) – Individual responsibility
Improper use of access systems (e.g. not closing hatches/using head to open/ kicking closed etc.)	– Points repeated from above – Too hot – keep hatches open for air flow – Hatches can be heavy – design issue – workaround – Carrying tooling makes it awkward – Sometimes opening with head is the only way – Ease – the design allows it – Laziness – Habit – Learnt behaviours – culture – Rushing – Don't understand implications of not doing it	– Some hatches/ gates are self-closing – Procedures in place – Systems in place, but not always followed – Spot audits/ inspections – Instructions – Training – Some design improvements – HAZIDS	– Design lighter hatches – Add barriers around hatches to allow them to be kept open safely – Risk assessments (is it actually 'bad' to open a hatch with your head for example?) – Use stairways instead of ladders – Material handling plans during design phase (for future and current turbine designs) – Air conditioning/ ventilation – Design hatches to open opposite way (ergonomics) – Assessment of current design for ergonomics – how do humans use them and how can this be done safely and easily? – More self-closing designs – Future designs – gaps to prevent trapped fingers – Capture issues at design phase early on – Pass on lessons learnt

Table A.4: Behavioural factors linked to unsafe acts (continued)

Unsafe act	Behavioural factors	Current control measures	Potential solutions/ improvement ideas
Rushing	– Time pressures – Unrealistic planning – Sudden weather changes – Management under pressure due to contractual commitments (availability) – Troubleshooting – Vessel crews as well as technicians under pressure – Cutting corners – Incentives – need to get job done – Too much documentation – Management expectations – Conflicting goals between management and supervisors for example – Need to get home – getting off turbine – Need to get turbine up and running again – Planning issues – Unexpected changes to plan – Fatigue – Lack of safety culture in industry with high turnover of contractors	– Site-specific – down to management team to filter attitude down to technician level – Plans will be in place, but can change at short notice for many reasons (e.g. weather)	– Better planning – Planners to get hands-on experience offshore to better understand tasks and times required – More experienced planners/leaders (people who were previously technicians for example) – Feedback from technicians – Eliminate need for servicing – conditioning monitoring systems, robots etc. – Plug and play components to reduce time and complexity of tasks – Management/ planning – don't start something that's too big for given time – Better communications – Prioritisation of tasks – Stick to agreed work tasks

Table A.4: Behavioural factors linked to unsafe acts (continued)

Unsafe act	Behavioural factors	Current control measures	Potential solutions/ improvement ideas
Poor housekeeping (e.g. tools/ spare parts lying around)	– Nowhere for equipment to go (this is site dependent) – Learnt behaviours – lead by example – Tool kits not suitable (e.g. if tray style kits used there is no room to store them) – Amount of equipment required to take onto turbine – Working parties getting bigger – Over planning for efficiency – i.e. trying to get more jobs done at once – Laziness – Not replacing broken tools – difficult to track – Doubling up of tools across shifts – Lack of time – rushing – Low perception of risk – Pride in work – if it wasn't tidy in first place might not care	– Better/more suitable tool kits – Supervision – Checklists – Lean servicing – set spaces for tools (5S system) – Storage units/ bins – Procedures – Workplace inspections	– Choose personnel based on experience of structured environments (e.g. military or experience with 5S etc.) – Reduce no. of tools required (plug and play components) – Baseline best practice – Consistency in supervision – Leave tool kits on turbine – Use of standard tools – 1 single bag which contains all required tools for the job – Better planning – work sequences – Better stores management – track and trace so it's clear what is already on a turbine – Keep everything in yaw deck and only bring up what you need – Recognition/rewards for good practice – 'Count it out/count it in' system – Cross-industry inspections

Table A.4: Behavioural factors linked to unsafe acts (continued)

Unsafe act	Behavioural factors	Current control measures	Potential solutions/ improvement ideas
Poor communications	– Language barriers – Varying risk perceptions – Experience levels vary – Some supervisors can be bad communicators – Over familiarity – Technology not suitable – Several groups working in different locations – Lack of time – rushing – Embarrassment (may not want to tell someone of higher rank what to do) – Laziness – Trust/team relationships – Poor quality working procedures/risk assessments/toolbox talks etc.	– Toolbox talks/ morning briefs which are mandatory – VHF radios – Mobile phones – Language crossover – Common language – Team building – Written instructions – Training	– Keep teams together across jobs for consistency – Organise work clusters close together – Site and safety managers should get hands-on experience on turbines – More consistency or better use of current control measures – Share good practice examples of toolbox talks – Strong leadership (clear instructions from top) – Specific training in communications related to what is required when moving around turbine

Analysis and findings

Across all the unsafe acts discussed, some common behavioural factors were noted:

Rushing due to:
- sudden unexpected changes;
- unrealistic planning;
- the need to get home, and
- pressure from management to meet contractual agreements.

Low perception of risk due to:
- complacency;
- learnt behaviours/culture, and
- lack of impact from training.

There are control measures in place for these issues; however, there is no consistency. Measures differ from site to site, which can cause problems in an industry which sees a high turnover of contract workers. Standardised approaches would be beneficial.

Recommendations

Potential solution suggestions focus on improving the measures which are already in place first and foremost:

- Improve planning by giving planners offshore experience.
- Strengthen leadership by selecting people who already have experience as technicians, as well as providing specific training in communications and leadership.
- Create a feedback route for technicians' findings to be provided to designers and planners.

Other suggestions look toward future ambitions:

- Reduction of time required on turbines with more standardised/plug and play type components.
- Elimination of time required on turbines by utilisation of self-maintaining parts, condition monitoring systems and robotic inspection and maintenance equipment.

ANNEX 2
ABBREVIATIONS AND ACRONYMS

5S	Sort, Set, Shine, Standardise and Sustain
EI	Energy Institute
ERP	emergency response plan
G+	G+ Global Offshore Wind Health and Safety Organisation
HAZID	hazard identification study
HAZOP	hazard and operability study
HSE	Health and Safety Executive
HSG	Health and Safety Guidance
OEM	original equipment manufacturer
O&M	operation and maintenance
PFPE	personal fall protection equipment
PPE	personal protective equipment
RAMS	risk assessment and method statement
SbD	Safety by Design
SCADA	supervisory control and data acquisition
SRL	self-retracting lifeline (lanyard)
TP	transition piece
VHF	very high frequency
WAH	working at height
WTG	wind turbine generator
Yo-yo	another term for an SRL

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